THE NEW GEOLOGICAL MAP OF RUSSIA[1]

GEOLOGISTS will be glad to hear of the appearance of the first sheet of the "Geological Survey of Russia," published by the Geological Committee on the scale of 10 versts to an inch. It comprises nearly the whole of the Government of Yaroslav and the eastern parts of Tver, between 57° 0′ and 57° 42′ N. lat., and 43° 10′ to 47° 40′ E. long., corresponding thus to Sheet 56 of the General Staff Map of Russia. This region, which is watered by the Upper Volga, the Mologa, and the Sheksna, is an undulating plain, the highest points of which, close to Bejetsk, reach 700 feet above the sea-level, gently sloping east and west to a level of from 350 to 420 feet. It has been dealt with first on account of a series of geological explorations which have already been made within its limits. It was visited by Blasius, Murchison, Keyserling, and Barbot-de-Marny, and careful explorations have been undertaken during the last few years within the limits of the province of Yaroslav, under the direction of its Provincial Assembly and Statistical Committee, by MM. Schurovsky, Piktorsky, Eremeyeff, Dittmar, Kryloff, and Nikitin.

The map, which has been prepared by M. Nikitin, is very carefully printed, and will be the more welcome to European geologists as all important names and explanations are given in French, side by side with the Russian text. The colours and the explanatory letterpress are in conformity with the recommendations of the International Geological Congress. A quarto volume, in Russian, by M. Nikitin, with plates and drawings, accompanies the map, the whole being summed up in German at the end of the volume.

The first thing which strikes one on looking at the map is the very great space covered with the gray colour of the Quaternary deposits. A greenish patch of Jurassic rocks in the middle of the map, several patches of Trias on its borders, and a very small Carboniferous patch, altogether hardly cover one-third of the surface; the remainder representing the "Boulder Clay, which conceals deposits of unknown age." The thick sheet of Boulder Clay will be for a long time the stumbling-block of Russian geologists. Natural sections are found only on the banks of the greater rivers, while the valleys of the smaller ones, to their very bottom, are cut through Quaternary deposits. Even the two railways that cross the space covered by the map have been laid without excavations of any importance to the geologist; and no artificial excavations worthy of notice are to be found in the whole area.

As to the geological description which accompanies the map, it is full of interest. The Carboniferous deposits which are denuded over a very limited space in the north-west, belong to the Upper series, characterised by *Spirifer mosquensis*. They probably extend throughout the region in nearly horizontal strata gradually inclined towards the east; but they are concealed by the Variegated Marls which are the subject of so lively a controversy among Russian geologists, and which are considered by the author as belonging to the Trias, contrary to the opinion of the Kazan geologists, who consider them Permian. Although appearing on the surface only in isolated islands, these Marls probably also extend throughout the Yaroslav region; the salt-springs at least, which appear at many places, and which usually take their origin, in Russia, either in the Devonian or in the Variegated Marls, seeming to indicate a great extension of these deposits. The Jurassic formations appear now (as throughout Middle Russia) only as sporadic islands, which are remains of a widely-extended strata destroyed by denudation; the Jurassic sea, according to the author, extending at least as far north as the latitude of Tver. The Jurassic deposits, which have been, like the Variegated Marls, the subject of special monographs by M. Nikitin, are represented in the Yaroslav region; the lower ones by the Callovian and the Oxford Clay, the two chief subdivisions of the former being characterised respectively by *Cadoceras Milaschevici* and *Quenstedioceras Leachi*, and those of the latter by *Cardioceras cordatum* and *C. alternans*. The Upper Jurassic is represented by the "Volga Series," Lower and Upper, respectively characterised by *Perisphinctes virgatus*, *Oxynoticeras fulgens*, and *Olcostephanus subditus*. They are invariably covered with a sheet of sands (like the Jurassic of Central Russia), which seems to have been a littoral deposit accumulated during the retreat of the Jurassic sea.

A very interesting chapter is devoted to the Quaternary deposits of Yaroslav and Central Russia. The thick sheet of Boulder Clay which covers Central and North-West Russia, and contains erratics from Finland and Olonetz, as also from those regions which the erratics had to cross on their way from the north, has long been a puzzle to Russian geologists. Within the limits of the map, it appears with its usual characters, that is, those of a layer 8 to 10 m. thick, spread without interruption over the country—over the watersheds as well as the valleys—without any traces of stratification or even of striation by water: the thickest boulders and the finest particles appearing closely mixed together without bearing any traces of sorting by water-currents. As to the boulders, they are of all possible sizes, from a grain of quartz to masses 2 and 3 m. in diameter. While crystalline rocks and schists from Finland and Olonetz are prevalent, local boulders—Carboniferous and sometimes Jurassic—are also not absent, especially in the lower strata. The boulders have a tendency towards a disposition in ridges which run from north-west to south-east, crossing the rivers, or rising sometimes in the shape of moraines, or eskers of great size. A sheet of boulder-bearing sand, with traces of stratification, appears at many places beneath the Boulder Clay, which passes also in its upper parts into an unstratified sand with boulders.

Such being the character of these deposits, it is obvious that the theory fails which tries to explain them by floating ice, as does also Prof. Trautschold's theory of "Eluvium." The author accepts, therefore, the theory now generally adopted by geologists, and specially advocated for Germany by Berendt, Penck, and Bernhardi, and for Russia by P. Krapotkin, and considers the Russian Boulder Clay as an equivalent of the *Krosstenslera* of Sweden. Like the British Till, it is no doubt the bottom-moraine of the great ice-sheet which covered Northern Germany and Russia, without reaching the Ural Mountains, during the ice-period. This period succeeded to a relatively mild climate, when the plains of Moscow were covered with thick oak and maple forests, inhabited by the mammoth and the rhinoceros, which were compelled by the ice-sheet slowly advancing from the north-west to emigrate east and south. The Loess of Southern Russia, and the Loess-like deposits of the intermediate region, were probably contemporary with the glaciation of the north.

Another chapter is devoted to the formation of rivers in European Russia, and to the great processes of denudation in the later parts of the Quaternary period. This subject has been keenly discussed of late by Russian geologists. The author is to be congratulated on the scientific manner in which he has laid the basis for a discussion of the three important questions—as to the Variegated Marls, the Boulder Clay, and the more recent alluvial deposits—with which he has had to deal in this first fascicule of the Geological Survey of Russia.

EARTHQUAKES

THOSE observers who have undertaken the detailed study of a region severely injured by an earthquake are well acquainted with the difficulties that attend on such a perilous and unthankful work as examining the ruins. The necessity is soon felt for some means of accurately registering the various characters of the earth's movement. The imperfect record of the features of an earthquake afforded by broken walls, fissured roofs, and overturned objects is dependent upon a variety of causes.

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[1] "General Geological Map of Russia." Sheet 56, Yaroslav, &c. By S. Nikitin. (*Memoirs* of the Geological Committee, vol. i. No. 2. St. Petersburg, 1884.)

1. The earthquake consists of a series of movements that do not radiate from a mathematical point, or even from the focal cavity, with perfect uniformity.
2. The group of disturbances which constitute a shock (of variable duration) may not arise from the same point, as, for instance, in the rending of a fissure in an upward direction, the first impulses would be derived from a much lower point than the last.
3. The great variation in the physical qualities of the rocks traversed, dependent upon their composition, intimate structure, and mode of arrangement. Also we may here include the irregular conformation of the surface.
4. The want of homogeneity and of regularity in the structure of houses and walls, and also the presence of door and window openings.
5. The presence of old fissures in buildings, either the result of displacement, shrinkage, or former earthquakes.

Were it possible to construct absolutely perfect instruments for registering the complex movements of an earthquake, we should be able to exclude the two important causes of error coming under the heads (4) and (5), but the others can never be removed, unless that under head (3) might be so by a complete knowledge of the subterranean geology of a district in question—a far from easy matter.

After perusing the recent paper by Prof. J. A. Ewing on "Measuring Earthquakes" (NATURE, vol. xxx. pp. 149 and 174), one might despair of ever understanding the complex tracings the author obtained. A more careful consideration of the subject would seem to help us out of the difficulty to a considerable extent in so far as theoretical reasons will permit us, and it is not till suitable seismographs have been fairly tried in other districts than the unsuitable alluvial plain of Yeddo that we shall learn whether there is any practical use in instrumental observation of earthquake movements.

In an alluvial plain like that of Yeddo, reposing as it probably does on the irregular surface of different but more elastic rocks, from which are transmitted to it the vibrations, the condition is such that a number of waves would be reflected and refracted so as to meet each other at various angles interfering with each other and producing very complex results on any pendulum instrument.

I am personally neither acquainted with the geology of the region in question nor with the type of disturbances constituting its earthquakes, yet from descriptions of the latter one would feel inclined to regard them as the tail-end movements of powerful shocks far below the surface, conditions highly favourable to complexity from reflection and refraction. Besides, the incoherent alluvium, often water-logged, is subject to a remarkable disturbance when vibrations are communicated to it from without, as may experimentally be illustrated by spreading jelly, or, better, mud, over the irregular surface of a piece of wood and tapping with a hammer.

These remarks may at first sight appear beyond the question, but we must not leave the subject without further trial. Any one who has studied the injuries resulting from destructive earthquakes such as that of 1857, described in Mallet's classical memoir, or of those of 1881 and 1883 in Ischia, cannot but be struck with the regularity of the injuries when the observer carefully excludes the large number of modifying influences, as heterogeneity in structure of buildings or the surface configuration of the point in question.

The following instruments were suggested by the study of the two great Ischian earthquakes, and with suitable modifications might be made appropriate to study small or great shocks as the case might require. The use of a pendulum as the main part of the mechanism has many objections, which have often been pointed out, and I think that future investigations will strongly confirm such opinions. Nevertheless I have given examples where the pendulum may be used, or replaced by other methods employing the same type of registering apparatus (Fig. 1). *a* is a pendulum with preferably a pear-shaped bob of great weight, which has attached to its lowest point a strong plaited thread of dentist's silk, *e*, which passes through a perforated glass plate, *d*. The hole in the glass plate is smoothly drilled of the exact size of the silk thread, so as to allow it to run easily but no more; it has its lip smoothly rounded off so that a section of the edge (see *d′*) is semicircular. The glass plate is firmly gripped by the horizontal metal plate *c*, which is rigidly fixed to the supports *b*, which in their turn are embedded in a solid masonry or rock basement. The silk thread is connected by a light wire cage, *f*, to the cylinder *g*, which slides easily up and down the fixed triangular column *h*. The cylinder *g* is connected to the writing arm lever *i*, which may be short, and write directly on the recording drum *k*, being then a simple stylus, or, as in the figure, arranged to magnify the amplitude two or more times at choice.

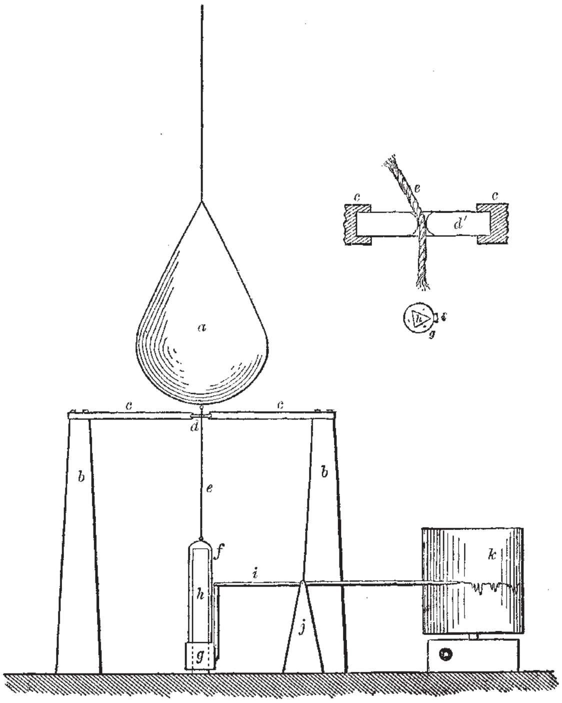

FIG. 1.—Pendulum apparatus to register amplitude of wave continuously.

When any earth-movements take place, the *relative* horizontal swings of the pendulum are converted into vertical movements of the silk thread, cylinder, and stylus, which on a time-ruled recording sheet will give accurate amplitude tracing minus the friction of the apparatus, which, if well constructed and the pendulum proportionally very heavy, may be excluded. By using a heavy pendulum with short suspension we may measure oscillations of short period, or, by using a long suspension and a delicate apparatus with greatly magnifying lever, this apparatus might be a useful tromometer, or measure of slow earth oscillations or tiltings (Fig. 2).

Three solidly-fixed cast-iron uprights, *a*, support a circular massive cast-iron plate, *b*, which has a conical aperture at its centre. Resting upon this is a circular sheet of plate-glass drilled at its centre in the same manner as the silk thread perforation in Fig. 1, as it serves a similar purpose. This glass plane must be perfectly horizontal. A circular disk of lead, *g*, is inclosed between glass planes, *d*, and rests on three perfect spheres, *f*, which should be preferably of glass or ivory. Rigidly attached at its centre on the lower side is a conical spire, *m*, whose point reaches just the level of the glass plane *c*, and has fixed to it the silk thread *n*. From the centre of the upper side projects the steel stylus *o*, bearing a fine platinum wire at its extremity, which may be used with the double azimuth circle of Fig. 3 in a direct manner in case of large earthquakes, or by a lever supported in gimbals, as also in Fig. 3. Another glass plane, *e*, with a large circular aperture at its centre for the free movement of the azimuth stylus *o*, has a wrought iron trellis work backing *h*. This reposes on the springs *k*, which are regulated by the milled-head screws *l*, so that it is only pressing sufficiently on the upper balls *f* to keep them in place. The upper springs *i* are introduced to allow slight freedom of motion to prevent breakage of the plates in almost vertical shocks or from the expansion of the lead disk, balls, &c. The silk thread is connected to the registering apparatus in the same manner as in Fig. 1, the slight weight of which will tend to draw back the rolling lead disk to its central position, and so prevent it shuffling out of its place, and yet have almost no effect in modifying the register of the absolute wave amplitude.

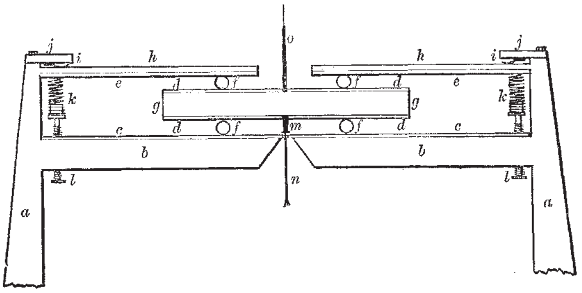

FIG. 2.—Ball and plane seismograph for indicating amplitude and azimuth in all phases of a shock.

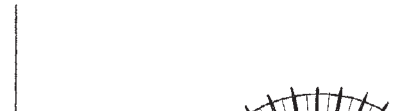

FIG. 3.—Azimuth register of wave path in all phases of an earthquake.

In working over an earth-shaken district of small area, such as that of Ischia, an error of observation of azimuth of even a few degrees matters little in determining the exact position of the epicentre. But on the contrary, in large areas such as the Neapolitan earthquake of 1857, and to a far greater extent in widespread disturbances such as the great Lisbon catastrophe, an error of a few minutes of a degree is sufficient to produce great divergence in the orientation of the azimuth and a consequent incorrectness in the location of the epicentre. In most seismographs so far employed, especially those of Italy, no attempt has been made to divide the circle into eight divisions, so that an error of nearly 45° could occur.

Fig. 3 represents a separate apparatus, although it would probably in practice be found preferable to replace the pendulum by the rolling disk and balls as already mentioned when describing Fig. 2, except that the contact rings *h* would then be inverted. A pendulum, *a*, with a length of suspension suitable to circumstances of observation, carries a steel spring wire, *b*, which slides in the cylinder *c*, which, together with the light wire arm *f*, forms a universal lever moving about the fulcrum at *d*, which are gimbals. This lever should be so balanced that, if placed in a horizontal position, the part above *d* should counterpoise the part *f*. The lever carries a fine platinum wire, *g*, which, when at rest, is the centre of the two contact circles *h*, *h'*, *h''*. This part of the mechanism is in connection with one pole of a battery.

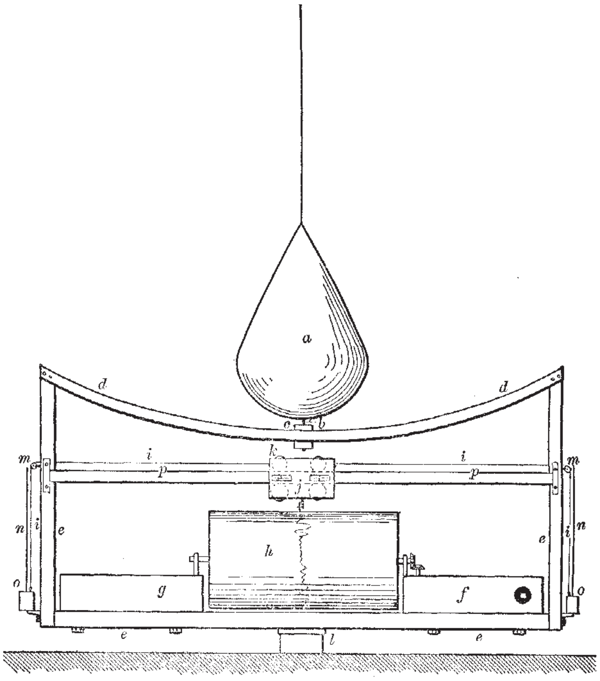

FIG. 4.—Horizontal component of wave-path register for strong and destructive earthquakes.

The contact circles *h* seen in detail, *h*, *h*, consist of a suitable number of brass segments, *l*, which have a V-shaped groove on their upper surface, and the edges, both inner and outer, are bevelled off. Each one is insulated from its fellow by the vulcanite plates *m*, which project a little on the inner, upper, and outer sides, and are sharpened to a knife edge.

The registering apparatus consist of a number of long soft-iron spring styles bolted to the column *i*, with their points near the revolving register cylinder *k*. A pile of electro-magnets, *j*, each of which is in connection with the two corresponding segments of the two contact circles and the battery, when the current passes, draws one soft-iron spring style towards its poles, and brings the point in contact with the cylinder *k*. The pendulum might be made to act directly on the contact circles without the magnifying lever *c f*, if thought necessary, and the breadth of the outer circle might be greater and give a correspondingly longer dash so as to distinguish those derived from the two circles.

It will be seen that the most complex movements of the pendulum or rolling disk can be accurately registered, since four contacts will be marked in each semiphase of the oscillation of the pendulum, and a fifth point can be obtained by calculation from the instrument for registering amplitude, which, together with the position of rest, will give sufficient data to obtain the loops for each semiphase throughout the disturbance.

In large earthquakes where the wave-amplitude is very great, the rolling disk and balls would require to be of very great size, which in many cases it might be impracticable to carry into execution, although the results might be of great perfection in so doing. The present instrument (Fig. 4) is intended to replace the rolling disk where that cannot be used of sufficient size.

A strong rectangular frame, *e*, carrying two strong uprights at its two extremities, is made so as to rotate with great facility around the vertical axis *l*. It supports the registering drum *h* with the clockwork arrangement *f* and a counterpoise, *g*. In practice it might be found advisable to attach these beneath the frame and so lower the centre of gravity of the whole apparatus. At a suitable distance above the drum a crossbar, *p*, is attached, which should be highly polished and square in section. The weight *j* should be made very heavy, and be allowed a very easy motion by means of four pairs of wheels, *k*, which are in contact with the crossbar *p*; these might be mounted on friction wheels (not shown in diagram). Attached on both sides of the weight are the silk threads *i i*, which traverse the upright, run over the pulley *m*, and are attached to the weights *o o*, which are only heavy enough to draw the weight *j* back to its place when it has been disturbed, that is to say, only just sufficient to overcome the friction of the wheels *k*. These weights, *o o*, are traversed by the guide wire *n* to prevent them dangling about during the swinging round of the frame.

The upper part of the frame carries two parallel bars, *d*, between which is a narrow groove to allow of the sliding of the plate *c*. They form the segment of a circle whose radius is equal to the length of the entire pendulum and its suspension. The pendulum *a* has fixed rigidly to its inferior extremity the steel axle *b*, which passes through the rectangular flat block *c*, which is prevented from slipping off by a bolt-head below, so that the flat block can rotate around the axle without falling off.

The action of the apparatus is as follows:—When an earth movement takes place the whole apparatus is brought into the azimuth of the wave-path by the oscillations of the pendulum *a* in that direction, which is affected by the block *c* sliding in the groove between the bars *d*. The pendulum should, in preference, have a short suspension, so that the period of its oscillations should be less than the wave intended to be registered by the apparatus, and should possess sufficient weight to have complete command over the frame, keeping it always in the wave-path azimuth. The weight will now appear to slide backwards and forwards on the bar *p*, registering its movements by the writing stylus, attached beneath it, on the drum *h*. The moment that *j* is moved from its central position one of the weights *o* is raised from its position of rest (these weights should preferably be hollow brass boxes into which only sufficient fine shot could be poured to overcome the friction of *j*), and rises as long as *j* continues to roll along the bar; if then the second half of the semiphase is not sufficient to bring it back to its normal position this will be done by *o*. When *j* has reached its central position, *o* will have come to rest at the base of the guide wire, and so no longer has any action, but is replaced in the second semiphase by its fellow of the opposite side. Of course the influence of the counterweights in retarding the rolling mass must be experimentally tried and taken into consideration in the calculations made from the tracings.

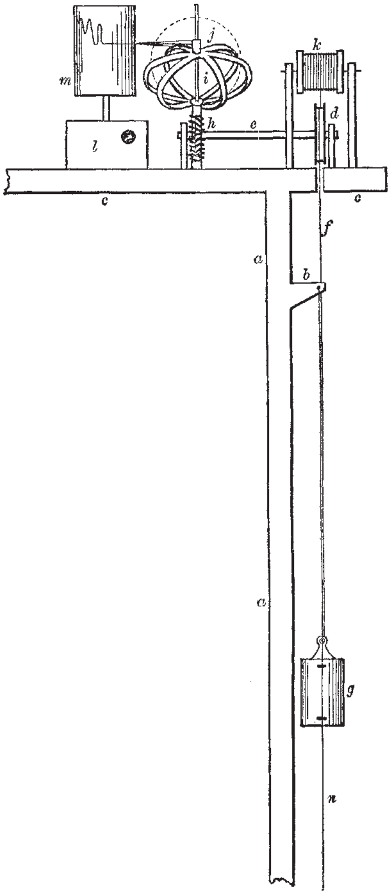

Fig. 5.—Apparatus for registering the vertical component of earth-waves during the whole of the disturbance.

The principle of this instrument is the acceleration and retardation of a falling body during each semiphase of an earth-wave. Fig. 5 illustrates a means of registering such changes in the rate of a falling body so acted on, although some other person better acquainted with mechanical movements might possibly suggest some improvement. A rigid vertical support of considerable length, *a*, is attached to the side of a well and is connected at its upper end to the table *c*; and by a small bracket *b* two vertical guide wires, *n*, pass through rings in the sides of the weight *g*, so far resembling Morin's apparatus illustrating the falling of bodies. Attached to the weight *g* is the silk thread *f*, which turns once or twice around the wheel *d*, and is supplied from the drum *k*. The wheel *d* is connected by the axle *e* and the continuous screw *h* to the apparatus *i*, which is a skeleton of flat steel springs, generally used to illustrate the distortion of a sphere by centrifugal motion. (I have proposed this in preference to the *ball governors* as retaining less impressed energy, which would unnecessarily complicate and even modify the results.) Sliding on the central axis of the spring sphere is a small cylinder, *j*, which is prevented from rotating by means of a ridge on its inner surface and a corresponding groove on the upright bar. This cylinder carries the writing arm and stylus, which registers on the cylinder the rising and falling of the former ; *l* is the motive power of the cylinder *m*. The apparatus for detaching the falling weight *g* is not shown in the diagram, but might be of the following arrangement :—A bob suspended by a spiral spring is made to make contact with a cup of mercury, as in the old form of vertical seismometers, besides a small lever of the first order attached at one end to the bob, the other extremity being above another cup of mercury. In this way, whether the movement of the bob be either up or down, in relation to the mercury cups, contact will be either made in the first case through the lever, or in the second directly by the bob. The current thus established could be used by an electromagnetic apparatus for removing a catch which holds the weight *g*. It could also start the cylinder *m* and stop a clock. The diagram will sufficiently explain the action of the apparatus.

If we review the advantages and disadvantages of the different instruments, I venture to say that, though far from perfection, they have much to be said in their favour. Their principal feature is the capability of registering continuously all the variations of the earth's movement during the complex disturbance known as an earthquake ; that by employing large tracing drums with a spiral arrangement and time-ruled paper, accurate time-records can be obtained for a considerable period and without interruption, so that a single observer could have under his command a large number of instruments, even at stations some considerable distance apart, thus resulting in much economy of trained observers. Then again the records are all permanent, being graphically inscribed. The instruments for registering azimuth and amplitude, and capable of doing so with the greatest delicacy and friction, in all cases can be reduced to a minimum, or easily calculated. With regard to the registration of the vertical component of an earth-wave, the old form of spiral spring and bob principle may be excluded from consideration as perfectly unreliable ; and even the improvements by Messrs. Milne and Ewing, and the ingenious idea of Mr. T. Gray, with its mercury trough compensator, cannot give accurate indication of the characters of a group of earth-waves. Another instrument worthy of trial is the hydrometer vertical-motion seismograph of Mr. T. Gray (*Phil. Mag.*, September 1881, p. 209). I think, however, that this instrument might be improved by using a long thin glass tube filled with air and floating in ether or some other fluid of very low viscosity. I would, however, venture to predict that a seismometer based on the principle of a falling weight, being accelerated or retarded according as the earth moves up or down, will supersede other methods, although no doubt such means of registering as described in this paper may be greatly improved upon.

The instruments described in this paper are all of considerable size, but it seems impossible to get good results unless heavy weights and their attendant mechanisms are used so as to reduce friction to a minimum in the consideration of results ; for it is certainly a pity to have imperfect results in consequence of limiting the size of the apparatus. One great objection to the falling weight seismometer is the necessity for a deep well, to give sufficient time to register an earthquake of ten or twenty or even more seconds' duration ; yet, by giving the weight more work to do by the introduction of multiplying wheels, this might be reduced as the circumstances might demand.

These instruments and the remarks on them are the outcome of long meditation while wandering over the ruins of two great earthquakes, and although expressed without a technical knowledge of mechanical construction, I hope I have made my ideas sufficiently clear.

H. J. JOHNSTON-LAVIS

INTERNATIONAL WEIGHTS AND MEASURES

IN inviting attention to the work done at Sèvres during the past year by the Comité International des Poids et Mesures,[1] we are glad to have the opportunity of congratulating those interested in accurate measurement on the fact that this country is now to be represented on the Committee, and will thus have a voice in their discussions. This, as we have pointed out on previous occasions, appears to be required of a country so largely interested in scientific research as ours.

METRES

Description of Standard	Error in terms of the true standard metre $(I_{2(0)}—6\mu)$	Mean coefficient of dilatation, 0° to t° C.
Standard I_2, which serves as the provisional standard of the Comité until the final prototype is verified ...	μ + 6·00	$10^{-9}(8594·6 + 1·26t)$
Standard I. for the use of the Bureau	+ 76·04	$10^{-9}(8602·9 + 2·09t)$
Standard II. for the use of the Bureau	+ 80·61	$10^{-9}(8569·1 + 2·79t)$
Standard III. for the use of the Bureau	+ 14·53	$10^{-9}(8560·0 + 1·63t)$
Standard XIII., belonging to French section of the Comité	+ 3·05	$10^{-9}(8540·6 + 2·62t)$
Bronze subdivided Standard N belonging to the Comité	+ 48·58	$10^{-9}(17483 + 7·07t)$
Brass Barometer-Standard T_1 belonging to Comité, constructed by Société genevoise pour la Construction d'Instruments de Physique	− 7·2	$10^{-9}(18178 + 7·9t)$
Brass Barometer-Standard T_2	− 31·6	$10^{-9}(18213 + 7·2t)$
,, ,, T_3	− 0·5	$10^{-9}(18037 + 4·7t)$
Brass Barometer-Standard constructed by Messrs. Hermann and Pfister, P ...	− 149·3	$10^{-9}(18821 + 8·4t)$
Platinum Standard for Spain originally constructed by Froment with lines traced by J. Alfonso, Secretary to Standards Commission at Madrid, E	+ 4·95	$10^{-9}(8898)$
Iron Standard of the United States Government made by Repsold, US	+ 97·8	$10^{-9}(10563)$
Standard for Office of Weights and Measures at Vienna, H_A	+ 14·1	$10^{-9}(18708 + 3·00t)$
Standard for Office of Weights and Measures at Vienna, A_A	− 8·9	$10^{-9}(17971 + 3·15t)$
Iron Standard of Société genevoise, F	− 31·4	$10^{-9}(11063)$
Brass Standard of Société genevoise, L	− 62·6	$10^{-9}(19155)$
Bimetallic Standard for French War Department, constructed by Porro—		
Brass, C	− 111·8	$10^{-9}(18699)$
Steel, A	+ 31·1	$10^{-9}(10420)$
Copper Standard for M. Tresca, Cu	+ 10·7	$10^{-9}(16334 + 5·82t)$
Green Glass Standard made by M. Baudin for thermometric purposes, V	+ 128·2	$10^{-9}(8392 + 4·8t)$

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[1] "Travaux et Mémoires," tome iii. 400 pages. (Paris : Gauthier-Villars, 1884.